BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF

ROCKPORT

MASSACHUSETTS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
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CORPS OF ENGINEERS
424 Trapelo Road
Waltham 54, Mass.

NEDGW 29 September 1961

SUBJECT: Beach Erosion Control Report on Cooperative Study of Rockport, Massachusetts

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.

SYLLABUS

The purpose of the study is to determine the best method of restoring the beaches and protecting the beach and cottage development.

The Division Engineer finds that since 1851 erosion has resulted in loss and recession of the beaches although some accretion has occurred since 1952, that recent replacement of failed sections of the seawall and the placement of riprap revetment along the toe of the new and existing wall now provides adequate protection for the development at Long Beach from direct wave attack, that continuation of erosion and loss of beach could gradually expose the existing development at Long Beach to more severe wave attack and damages and that all beach areas are subject to minor damages from wave runup and landward movement of beach material.

The Division Engineer has developed a practicable project for improvement and protection of Long Beach upon the request of the cooperating agency although construction of this project at the present time is not warranted by evaluated benefits. This project consists of widening 3,300 feet of the beach by direct placement of sand fill and construction of a training jetty at the tidal creek at the east end of the fill. The Division Engineer has also developed a practicable method for reducing overtopping of Pebbly Beach for use by local interests.

The Division Engineer recommends that no project be adopted by the United States and that protective measures that may be undertaken by local interests based upon their determination of economic justification be accomplished in accordance with plans and methods considered in his report.

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF

ROCKPORT, MASSACHUSETTS

PART I - GENERAL

1. Authority. - This study was made by the Corps of Engineers, United States Army, in cooperation with the Division of Waterways of the Massachusetts Department of Public Works under authority of Section 2 of the River and Harbor Act approved July 3, 1930, as amended and supplemented. The formal application for the study dated October 29, 1958, was approved by the Chief of Engineers on April 3, 1959.

2. Purpose. - The purpose of the study as stated in the formal application, is to determine the best method of restoring the beach and protecting the beach and cottage development. Its purpose is also to determine the justification and amount of Federal participation that is warranted in any recommended plans of improvement in accordance with the policy established by Public Law 826, 84th Congress.

3. Prior Reports. - There have been no prior beach erosion control reports covering the study area. Numerous navigation studies of harbors located in the general vicinity have been made. The latest published reports are as follows: (1) Gloucester Harbor, House Doc. 329, 77th Congress, 1st Session; (2) Sandy Bay, Cape Ann (Harbor of Refuge), House Doc. 3, 65th Congress, 1st Session; and (3) Rockport Harbor, House Doc. 363, 56th Congress, 1st Session. These navigation reports contain some general information which is pertinent to the beach erosion control study.

4. Description. - The study area is located in the town of Rockport and the city of Gloucester in Essex County, Massachusetts. It is situated about 30 miles northeast of Boston on the south side of Cape Ann, a rocky headland which forms the northern limit of Massachusetts Bay. The study area consists of three barrier pocket beaches between the rocky points at Brier Neck and Lands End. It has a total length of approximately 1.5 miles, 0.1 mile in Gloucester and 1.4 miles in Rockport. The pocket beaches are known as Long Beach, Cape Hedge Beach, and Pebbly Beach. They are shown on United States Coast and Geodetic Survey Coast Charts 243 and 1206, on the U. S. Army Map Service topographic quadrangle of Rockport, and on Plate 1 and Photos 1 through 9 of this report.

5. The permanent populations of Essex County, the town of Rockport, and the city of Gloucester in 1960 were 568,831, 4,616, and 25,789, respectively, an increase since 1950 of 10 percent for Essex County and Rockport and about 700 people for Gloucester. The above

populations are greatly augmented by seasonal residents and tourists during the summer. The town of Rockport and the surrounding region contain a large number of tourist accommodations with about 750 rooms available for rental in Rockport alone. The city of Gloucester is one of the largest commercial fishing ports in the United States. It has fish processing plants, manufacturing establishments and extensive boatyard and marine railway facilities. The region is easily accessible over highways and local roads. There is no known water pollution of any consequence along the shore of the study area.

6. Long Beach is the most westerly of the three pocket beaches. It has a length of about 3,800 feet between Brier Neck and a protruding rock outcrop known as Cape Hedge. The westerly 500 feet of shore at Brier Neck is located in the city of Gloucester and except for two public street ends, this area is privately owned. Development along the Gloucester shore consists of motels, bathhouses, guest houses, restaurants, refreshment stands, and limited parking areas. The remaining 3,300 feet of shore is located in the town of Rockport. Lots in the backshore behind a concrete seawall are leased to private individuals. This backshore area has been intensively developed for summer cottage use. Access to and use of the backshore is limited to residents. The beach fronting the concrete seawall is maintained by the town for public recreational use. Public access and limited public parking are available only at the ends of the beach. The beach is composed of fine to medium sand. Its width above the high water line in front of the seawall in Rockport decreases from east to west from about 40 to 150 feet. The width decreases westward along the Gloucester shore of Brier Neck from about 150 to 50 feet. The backshore behind the seawall is composed of sand dunes fronting marsh. The marsh is drained by a tidal creek which enters the ocean at the east end of the beach adjacent to Cape Hedge.

7. The central pocket, Cape Hedge Beach, has a length of 2,000 feet between rock outcrops. It is entirely owned by the town of Rockport and it is open for public use. There is no development at Cape Hedge. The area behind the west half of the beach is a public parking area accessible by a road over the marsh. Development at the privately-owned rocky promontory at the east end of the beach consists of inns, hotels and residences. The beach is a barrier bar fronting marsh and a pond. There is a natural barrier consisting of high peaked steeply sloping shingle ridge along the west half of the beach. Its top gradually flattens and drops in elevation eastward from its midpoint from an elevation of 22 feet to about 16 feet above mean low water. Its composition also changes eastward, becoming finer, with some sand mixed with the shingle. At its west end, the shingle slopes steeply down to the low water line. As the ridge diminishes in size eastward, its seaward slope intersects the beach at a higher level so that at its east end there is a narrow width of fine to medium sand beach above high water. The east end of the beach below high water is

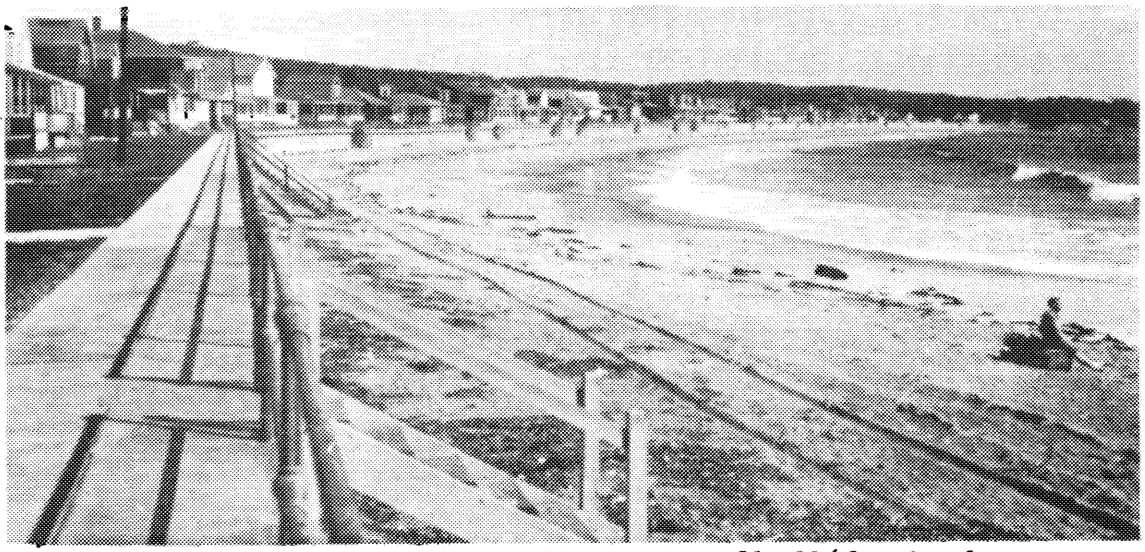


PHOTO 1 LONG BEACH, ROCKPORT, Sept 21, 1960 - Sandy beach from end of seawall at Gloucester-Rockport boundary.


PHOTO 2 LONG BEACH, ROCKPORT, April 8, 1961 - Stone apron uncovered by seasonal lowering of beach.


PHOTO 3 LONG BEACH, ROCKPORT, April 30, 1958 - Concrete seawall lying on beach was destroyed by storm of April 1-2, 1958. Temporary bulkheads protect cottages.

PHOTO 4 LONG BEACH, ROCKPORT, Sept 21, 1960 - Newly constructed seawall starts beyond first steps.

PHOTO 5 LONG BEACH, ROCKPORT, Sept 21, 1960 - Exposed stone apron near tidal creek at east end of beach.

PHOTO 6 EAST END OF LONG BEACH, ROCKPORT, Sept 21, 1960- Tidal creek and Long Beach from shingle ridge at Cape Hedge Beach.

PHOTO 7 CAPE HEDGE BEACH, ROCKPORT, Sept 21, 1960 - Shingle ridge from west end of the barrier beach.

PHOTO 8 CAPE HEDGE BEACH, ROCKPORT, Sept 21, 1960 - East end of beach. Sandy foreshore and shingle ridge fronts marsh.

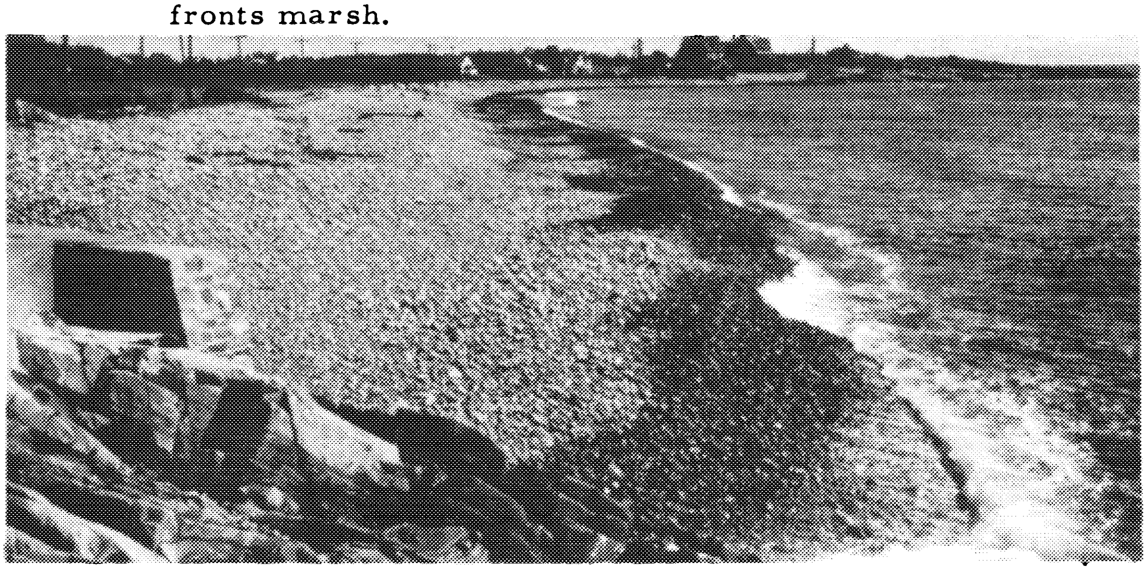


PHOTO 9 PEBBLY BEACH, ROCKPORT, Sept 21, 1960 - Steep shingle beach. Lands End in the background.

composed of medium to fine sand but it is seasonally covered with shingle. The entire beach in the vicinity of low water is composed of fine sand.

8. The east pocket, Pebbly Beach, has a length of about 1,700 feet between the rock outcrops at South Street and Lands End. The central 1,040 feet of shore belongs to the town of Rockport and the remaining shore front at both ends is privately owned. There is an unpaved road immediately behind and parallel to the beach. The road is separated from the beach by a low ridge composed of shingle, cobbles, boulders and riprap. Development at Lands End is residential. The beach is a barrier bar fronting marsh and a pond. The usable width of the beach above high water varies from about 40 to 60 feet. In the vicinity of Lands End the shore is covered with cobbles and boulders out to low water. This coarse cover diminishes westward and ends about 500 feet from Lands End. Portions of the east half of the beach landward of the low water line consist of fine and medium sand. The entire beach consists of fine sand in the vicinity of the low water line. The beach above low water becomes increasingly covered with shingle to the west, the amount of such cover varying seasonally.

9. Statement of the Problem and Improvements Desired. - The problem consists of erosion of the beaches, particularly during storms, damages to the existing protective structures and development due to wave attack and undermining, overtopping of beaches by wave runup with consequent deposition of beach material and debris on adjacent roads and developed areas, and the meandering of a tidal drainage creek across the east end of Long Beach. The application for this study was initiated as a consequence of a severe storm on April 1 and 2, 1958 which caused erosion of Long Beach, lowering of the beach level, undermining and failure of approximately 1,600 feet of concrete seawall and damages to cottages situated on dunes behind the failed wall sections. Since initiation of the study, the State has rebuilt the seawall. Meandering of the tidal drainage creek at the east end of Long Beach has resulted in erosion and narrowing of the beach. Wave runup during storms overtop Cape Hedge and Pebbly Beaches washing material landward onto the parking area and marshes at the former location and onto the bordering shore road and marshes at the latter.

10. Two meetings were held leading to application for the study, one on 8 April 1958 with a United States Congressman and Selectmen of the town of Rockport, the other on 30 April 1958 attended by representatives of the Beach Erosion Board, the State, county, the town of Rockport and the U. S. Army Engineer Division, New England. At that time, town and State officials indicated a desire to obtain Federal assistance in construction of protective works for the development at Long Beach where seawall failures had occurred. Additional meetings where held with officials of the town and the cooperating agency, the State, during

the study. After replacement of the seawall at Long Beach by the State, town officials indicated that there were no other serious problems for which they desired improvements. The cooperating agency, however, requested that a plan be developed for possible future use consisting of widening Long Beach by the placement of sand fill and for training the inlet at its east end.

PART II - FACTORS PERTINENT TO THE PROBLEM

11. Geomorphology. - Cape Ann, is a rocky headland separated from the mainland, to the west, at Gloucester, by the Annisquam River. The bedrock comprising this headland is igneous in origin, consisting mostly of granite. Rock is exposed at many places. Except at outcrops, this bedrock is covered by a very thin overburden of glacial till. The ragged shore line of southeastern Cape Ann which includes the study area, Gloucester Harbor and Sandy Bay is the result of the uneven composition of the igneous rocks and the consequent differential erosional development. The pocket beaches in the study area were formed by erosion, movement sorting and deposition of former rocks and glacial till. Landforms and gradation of coarse materials indicate that littoral drift northeast of Brier Neck moves in a northeasterly direction.

12. Littoral Materials. - a. Characteristics. - Character of littoral materials in the study area was determined from surface samples taken along beach profiles from the seawall or beach berm out to the 30-foot depth. Samples on three profiles were taken at Long Beach and one profile each at Cape Hedge and Pebbly Beaches. The results of the sample analyses are included in Appendix A. Character of materials offshore opposite Lands End and in the tidal creek area behind Long Beach was determined by probings. Locations of probings and material encountered are shown on Plate No. 1. General descriptions of beach composition based on visual inspection are contained in preceding Paragraphs 6 through 8. Samples taken along the profiles at Long Beach indicate the material is principally fine sand distributed uniformly through all zones from the beach berm to the 30-foot depth. The highest percentage of medium sand occurs between the 6 and 12-foot depths. The median diameters of the samples increase slightly from west to east in the upper regions of the beach above mean low water, while in the area below low water, the median diameter increases from east to west. At Cape Hedge Beach, the samples above the 6-foot depth consist mostly of gravel with mixtures of coarse to fine sand. From the 6 to the 18-foot depth over 90 percent of the material is fine sand. The samples at Pebbly Beach range from coarse gravel to fine sand. A large part of the beach above mean low water is gravel. From the 6 to 12-foot depth over 80 percent of the material is fine sand.

b. Sources. - The materials comprising the beaches in the study area are derived from eroded rocks and to a lesser extent, glacial till overlying bedrock. Little or no overburden remains on the headlands. Since no overburden areas in the vicinity are exposed to erosion and since little sand can bypass the larger headlands, the supply of material to the beach is meagre, probably mostly produced by local rock erosion. Probings offshore opposite Lands End indicate that no overburden exists on the bedrock. Probings along the tidal creek, landward of the eastern end of Long Beach, indicate the existence of sand and gravel varying in depth from 6 to 20 feet. Further investigation would be required to determine if this area is a suitable source for borrow. Preliminary reconnaissance for land borrow in the vicinity showed no source of materials available. It is believed that suitable beach fill could be obtained within a haul radius of 10 to 15 miles.

13. Littoral Forces. - a. Waves. - The study area is directly exposed to wave action from the southeast quadrant with an unrestricted fetch across the Atlantic Ocean. No wave measurements are available for the immediate area. Hindcast wave data based on synoptic weather charts for locations along the North Atlantic coast have been prepared and published by the Beach Erosion Board. A wave rose from this data for a location off Nauset Beach, Cape Cod, Massachusetts is shown on Plate No. 1. It indicates that waves occur with greatest frequency from the northeast and east directions. Waves from the southeast quadrant which can approach the study area more directly occur with considerably lesser frequency. The shore is sheltered by the mainland from the north and west. The fetch to the south across Massachusetts Bay is limited by Cape Cod and the mainland.

b. Currents. - Tidal currents along the coast flood to the north and ebb to the south. Maximum average velocities of ocean currents north and south of the study area vary from 0.3 to 0.8 knots. Higher flood and ebb currents occur at the northeast end of Long Beach at the entrance to the tidal creek at Cape Hedge.

c. Winds. - Records of winds observed by the United States Weather Bureau at Boston, Massachusetts for the ten-year period, October 1949 to September 1959 show that prevailing winds blow offshore from westerly directions. Winds which blow onshore prevail from the east southeast but winds from the east to northeast which occur for a shorter duration have a higher average velocity. A wind diagram based on data from the Boston Weather Bureau is shown on Plate 1. A summary of the data and more detailed descriptions are included in Appendix B.

d. Storms. - Records from the United States Weather Bureau at Boston, Massachusetts for the 75-year period 1870-1945, inclusive, show a high preponderance of northeast storms. These storms represent major disturbances of considerable duration, often accompanied by rain or snow, and high tides causing damage to low-lying shore developments. The wind rose on Plate No. 1 shows storm winds from the northeast occur most frequently. The study area is sheltered in this direction by the mainland and offshore islands. The shore is directly exposed to storms from the southeast from which direction storm winds are least frequent and of short duration. More detailed storm data are included in Appendix B.

e. Tides. - Tides are semi-diurnal. The mean tidal range is 8.6 feet at the Rockport Harbor entrance and 8.7 feet at Gloucester Harbor. Corresponding spring ranges are 10.0 and 10.1 feet. The estimated highest tide experienced at Gloucester Harbor is 13.0 feet above mean low water. Based on averages from a 30-year record, tides at Boston exceed the plane of mean high water by 2 feet or more 24.5 times a year, by 3.1 feet or more about once a year and by 3.5 feet or more 0.2 times a year. Comparison of high tides which have occurred at Boston and Gloucester over a three-month period indicate that tides at Gloucester vary from the mean range about the same as at Boston. More detailed information concerning tides is contained in Appendix C.

14. Shore History. - a. Shoreline and Offshore Changes. - Shoreline and offshore depth changes were determined from comparative positions of the high water shoreline located in 1851, 1952 and 1960, from the 6, 12 and 18-foot depth contours located in 1853 and 1873 and from beach profiles surveyed in 1960. Amounts of change were determined by scaling from available maps and they are, therefore, only approximate. The changes are shown on Plates 2-6. Between 1851 and 1952, the shoreline receded throughout the study area but from 1952 to 1960, comparative positions indicate a slight accretion. The amounts of high water shoreline changes are tabulated below:

HIGH WATER SHORELINE CHANGES (1851-1960)

Long Beach

Period	Location and Length	Change
1851-1952	Westerly 600'	Recession 0-140'
	Easterly 3200'	Recession 0-190'
1952-1960	Westerly 2000'	Accretion 0-40'
	Easterly 1000'	Accretion 0-30'

Cape Hedge Beach

Period	Location and Length	Change
1851-1952	Westerly 1300'	Recession 0-230'
	Easterly 700'	Recession 0-290'
1952-1960	Easterly 1800'	Accretion 0-40'

Pebbly Beach

Period	Location and Length	Change
1851-1952	Westerly 200'	Recession 0-70'
	Next Easterly 500'	Recession 0-40'
	Easterly 800'	Recession 0-90'
1952-1960	Westerly 200'	Accretion 0-40'
	Easterly 800'	Accretion 0-30'

Determination of movements of the 6 and 12-foot depth contours was limited by available comparative data to the period 1873 and 1960, for the east end of Pebbly Beach where the 6-foot depth contour moved landward about 120 feet while the 12-foot contour remained unchanged. Movements of the 18-foot depth contour determined from the 1853 survey and the 1960 beach profiles were as follows: 230-foot landward at the west end of Long Beach at Profile 1 decreasing to 30 feet at the center of Long Beach; little or no change from Profile 4 at Long Beach to Profile 6 at Cape Hedge Beach; landward at Cape Hedge Beach increasing up to 210 feet from Profile 6 to Profile 8 and decreasing to little change at Profile 9; seaward, 80 and 150, respectively at Profiles 10 and 11 at Pebbly Beach.

b. Prior Corrective Action and Existing Structures. The State, town, and private property owners have protected portions of the shore by the construction of protective works. Prior to the construction of the existing concrete seawall at Long Beach, the town of Rockport built a timber bulkhead about 3,300 feet long to protect the sand dunes forming the beach crest. Details concerning the structure are not known. This bulkhead was completely destroyed by a storm on March 4, 1931. Construction of a concrete seawall to replace the bulkhead was started by the Massachusetts Department of Public Works in the fall of 1931 and completed in 1932, at a cost of $53,000, including $26,000 contributed by the town of Rockport. The seawall was constructed in front of the sand dunes from the Gloucester town line to the tidal creek at Cape Hedge. The wall at its east end was turned inland along the west bank of the tidal creek. In January 1933, this wall was weakened by a severe storm. To prevent further damage, about 2,000 tons of stone riprap was placed at the seaward toe of the wall starting at a point 400 feet from the west end of the wall and extending eastward about 800 feet. On 1-2 April 1958, storm waves undermined the seawall causing two sections to fall forward onto the beach. The failed sections had lengths of 330 and 1,280 feet and they were located 80 to 410 and 1,550 to 2,830 feet, respectively, from the west end of the wall. This exposed the sand dunes and summer cottage development to damage from wave attack. Temporary stone riprap and wooden bulkheads were placed in these exposed areas following the storm. The destroyed sections of the wall were reconstructed by the Massachusetts Department of Public Works during 1959 at a cost of $223,500. The riprap used for temporary protection on the dunes was incorporated into a stone apron twenty feet wide placed at the seaward toe of the wall thereby providing revetment along the toe of the entire old and new sections of the Long Beach seawall. The original gravity type seawall built in 1931-32 had a top elevation of approximately 21 feet above mean low water, a top width of 3.5 feet, and a bottom elevation varying from +10 to +12 feet. The new wall sections are of cantilever design and have the same general dimensions as the old wall. The concrete footing of the new wall has a top elevation of +10 feet, is two feet thick and six feet wide. Typical cross sections of the old and new walls are shown on Plate 7. There are three other structures within the study area. A vertical faced concrete seawall exists at South Street at the east end of Cape Hedge Beach. It is about 90 feet long with a top elevation of +17.0 feet. It protects the end of South Street and adjacent private property. A riprap mound fronting an unpaved road has been built by the town of Rockport along 600 feet of Pebbly Beach and a mortared stone wall fronts the grounds of private property at the east end of Pebbly Beach.

c. Profiles. - Eleven beach profiles were surveyed in 1960 at selected locations in the study area, as shown on Plate 1. They varied from 1,500 to 2,000 feet in length and extended from the beach crest seaward to depths of 30 to 35 feet below mean low water. Plots of the profiles are shown on Plates 3 to 6. Beach slopes were measured from the plotted profiles and they are shown in the following table. Slopes are given from the landward to the seaward ends of the profiles, thus; 1/25 above - 10.0 meaning one vertical over 25 horizontal above an elevation of 10 feet below mean low water. Slopes flatter than 1/100 are listed as level. Because of a lack of detailed surveys in the area prior to 1960, no comparison of beach profiles could be made to determine quantities of accretion or erosion.

PROFILE NO.	BEACH SLOPES
	LONG BEACH
1	Beach berm from wall to 12.5; 1/9 from 12.5 to 6.5; 1/39 from 6.5 to -33.0
2	Beach berm from wall to 13.3; 1/30 from 13.3 to 11.5; 1/10 from 11.5 to 6.5; 1/39 from 6.5 to -33.0
3	1/25 from wall to 11.0; 1/9 from 11.0 to 6.5; 1/39 from 6.5 to -35.0; level
4	1/9 from wall to 8.5; 1/39 from 8.5 to -31.0; level
5	1/23 from wall to 12.5; 1/8 from 12.5 to 8.0; 1/39 from 8.0 to -30.0
	CAPE HEDGE BEACH
6	1/5 above M.H.W.; 1/16 from M.H.W. to M.L.W.; 1/40 from M.L.W. to -32.0; level
7	1/5 above M.H.W.; 1/14 from M.H.W. to M.L.W.; level, 1/32 from -1.0 to -29.0; 1/60 from -29.0 to -34.0
8	1/9 above M.H.W.; 1/20 from M.H.W. to M.L.W.; level, 1/32 from -1.0 to -28.0; 1/60 from -28.0 to -33.0
	PEBBLY BEACH
9	1/5 above 4.0; 1/15 from 4.0 to M.L.W.; 1/40 below M.L.W. to -30.0
10	1/7 above M.H.W.; 1/14 from M.H.W. to M.L.W.; 1/40 M.L.W. to -27.0; level
11	1/15 above -2.0; level, 1/44 from -2.0 to -26.0; level

PART III - ANALYSIS OF THE PROBLEM

15. Shore Processes Pertinent to the Problem. - The loss of beach materials and damages to shore structures are caused principally by wave action. Movement of material is probably largely on and offshore with offshore movement resulting from short period locally generated waves nearly balanced by onshore movement in calmer periods resulting from swells. The on and offshore movement is responsible for seasonal changes which occur to the level and composition of the beach. Tidal inlet currents cause some loss and narrowing of the east end of Long Beach. Some material is lost by landward movement over Cape Hedge and Pebbly Beaches into the ponds or marsh by overtopping storm waves. Undermining and damages to shore structures have occurred following seasonal changes when the beach was at a low level. The form and gradation of the beach indicates that littoral drift moves in an eastward direction but this movement is limited by the lack of an appreciable source of supply. Net losses of material from the beaches which probably occur at a slow rate could gradually expose the existing development to more severe wave attack.

16. Methods of Correcting Problem Conditions. - Long Beach can be improved by artificial nourishment with sand fill to provide a wider protective beach or additional recreational beach area. Probings behind Long Beach in the vicinity of the tidal creek indicate that sand suitable for beach nourishment may exist but further investigation would be necessary to determine if this source is adequate. Material might have to be obtained by borrow from available inland sources. A jetty could be constructed at the east end of Long Beach to control the currents at the inlet of the tidal creek and reduce losses of beach material. The existing Long Beach seawall and riprap toe revetment are adequate for protection of the development against direct wave attack although some minor damages can occur as a result of wave runup and spray during severe storms. Reduction of losses of beach material over Cape Hedge and Pebbly Beaches can be prevented or reduced by the construction of barriers to landward movement. Armoring the shore by the construction of seawalls or revetments as has already been done is a suitable method of protecting developed areas. This latter method would not contribute significantly to the creation of a fronting beach. Groins or breakwaters are not considered to be suitable methods of protection for this area.

17. Design Criteria. - Proposed protective measures are designed to provide protection for ordinary conditions of comparatively frequent occurrence (about once a year). They are not intended to provide complete protection in the event of hurricanes or great storms of infrequent occurrence, although even under these conditions some protection will be afforded.

a. Design Tide. - The design tide is the maximum elevation which occurs about once a year. The elevation of design tide is 11.8 feet above mean low water.

b. Design Wave. - The maximum heights of the design wave were determined from the relationship $^{d}/H = 1.28$ where d is the depth of breaking and H is the height of wave at breaking using the depth at the proposed structure at time of design tide as the depth of breaking. The design wave at the seaward end of the proposed jetty at Long Beach is 7.0 feet and at a point 70 feet landward from the outer end is 5.6 feet.

c. Sizes and Slopes of Armor Stones in Structures. - Sizes and slopes of cap and armor stones for the training jetty are computed using the United States Army Waterways Experiment Station Formula with a minimum size armor stone of one (1) ton, the size required for a design wave of 5.6 feet. The minimum size and the slopes for the proposed mound at Pebbly Beach were based on judgment without use of the WES formula since the mound will be located in a zone of the beach above design tide level where no waves exist during design conditions.

d. Training Jetty. - The horizontal inshore section should ordinarily have a top elevation higher than the general height of the berm of the existing beach and a length not less than the berm width of the anticipated beach. The existing beach level indicates that a top elevation of 15.0 feet above mean low water should be used. The intermediate slopes section should not be steeper than the slope of the existing bottom. For stone construction the jetty should have a minimum height of five feet to permit use of the required size of armor stones and a sand-tight core. The jetty should be firmly anchored at its inshore end to prevent flanking. Blankets of spalls or crushed stone are used under stone jetties to minimize settlement due to scour.

e. Sand Fill. - The berm elevation of the proposed sand fill is based on that at the existing beach. The minimum width of fill between the high water line and shore structures is based on widths found to afford protection in the area. Estimated volumes of fill are based on slopes similar to existing slopes but fill can be placed initially to a steeper slope and permitted to take a more natural slope under wave action. Based on these criteria the beach width between the seawall and the high water shoreline is 150 feet, the berm elevation is 14 feet above mean low water and the fill slopes are 1 on 15 and 1 on 30 respectively above and below elevation +7.5 feet. Suitable sand for beach fills would have size and gradation characteristics similar to those of existing beach materials. For the purpose of detailed design of the beach fill, the investigations of materials on the beach and in proposed borrow areas should be supplemented when plans and specifications are being prepared.

PART IV - PLANS OF PROTECTION

18. Long Beach. - A plan for protection and improvement of approximately 3,300 feet of Long Beach between the Gloucester-Rockport boundary and the tidal creek at Cape Hedge has been developed upon the request of the cooperating agency for possible future use by local interests even though the problem conditions do not warrant its construction at the present time. It consists of widening the beach by direct placement of sand fill and the construction of a training jetty at the mouth of the tidal creek. The fill would widen the beach to a 150-foot width between the existing seawall and the proposed mean high water line thereby providing protection against wave attack and additional area for recreational use. The training jetty would have a length of 400 feet, a top elevation of 15 feet at its inshore end and 11 feet at its outer end, a minimum height of 5 feet, side slopes of 1 on 1.5 and a top width of 5 to 6 feet, the latter along the outer 100 feet. The jetty would retain the proposed fill and control the tidal inlet currents thereby reducing losses of beach material and narrowing of the beach. If protection against closure of the inlet by littoral drift should become necessary, the jetty could be lengthened by extending it seaward. The need for such protection is not evident at the present time. The plan is shown on Plate 7.

19. Cape Hedge Beach. - No detailed plan of protection has been developed for Cape Hedge Beach. The hugh shingle ridge fronting the parking area provides considerable natural protection. Landward movement of material during storms could be reduced or prevented by the construction of a seawall, mound or some other form of barrier. Under the present condition of use and lack of development, construction of a barrier of the magnitude required does not appear to be warranted. Cleaning of the parking area as needed and restoration of the displaced material onto the fronting beach and shingle ridge is probably the most economical method of maintenance.

20. Pebbly Beach. - Landward movement of beach material onto and over the access road behind Pebbly Beach can be prevented or reduced by construction of a barrier along the seaward edge of the shore road. A typical section of stone mound which would be suitable for this purpose has been developed for possible use by local interests and it is shown on Plate 7. The mound has a top elevation of 20 feet above mean low water, a top width of 3 feet, a seaward side slope of 1 on 1.5 and a landward side slope of 1 on 1. Construction of a concrete seawall, curb or other form of barrier would also be suitable.

PART V - ECONOMIC ANALYSIS

21. First Costs and Annual Charges. - Total first costs and annual charges were estimated for the beach widening and training jetty construction considered for Long Beach. The cost per linear foot was estimated for the stone mound construction considered for Pebbly Beach. The cost of sand fill was estimated on the basis of dry borrow and trucking. Costs were based on price levels prevailing during August 1961. An economic life of 50 years was used in determining amortization charges. An interest rate of 3.5 percent was used for annual charges which are all non-Federal. The annual maintenance requirement for beach fill was based on losses estimated from the maximum average shore line recession of 1.8 feet per year which shore line comparisons showed occurred between 1851 and 1952. Estimated losses during this period were 3-1/3 cubic yards per linear foot per year. Annual maintenance cost of the training jetty was based on replacement of one percent of the quantity of stone per year. Estimates are as follows:

LONG BEACH, SAND FILL AND TRAINING JETTY

First Costs		
Sandfill - 100,000 cu. yds. at $1.25		$144,000*
Training Jetty - 2000 tons Armor and Core Stone at $7.50		17,300*
- 800 tons Bedding Stone at $4.00		3,700*
	Subtotal	$165,000*
Engineering and Design		5,000
	Subtotal	$170,000*
Supervision and Administration		14,000
	Total First Cost	$184,000*
Annual Charges (Non-Federal)		
Interest (.035 x $184,000)		$ 6,440
Amortization (.00763 x $184,000)		1,410
Maintenance		
Training jetty, 20 tons at $10.00		200
Sandfill, 11,000 cu. yds. at $1.25		13,750
	Total Annual Charges	$ 21,800

*Includes Contingencies

PEBBLY BEACH, UNIT LENGTH OF STONE MOUND

First Costs

Stone, 2.6 tons at $6.00		$ 18.00*
Engineering and Design		1.00
	Subtotal	$ 19.00*
Supervision and Administration		2.00
	Total First Cost	$ 21.00*

*Includes Contingencies

22. Benefits. - No recreational benefits could be evaluated for Long Beach since the existing beach area is adequate for present or prospective needs. Public recreational benefits could be realized from the proposed beach widening if facilities were provided for better public access to and use of the beach. Local interests have not indicated any intent or desire to provide such facilities and it is not expected that they will do so. The sand fill by dissipating wave energy would reduce damages to existing public protective structures and private cottages. The public benefit from prevention of direct damages to the riprap revetment fronting the seawall is estimated as the cost of replacing 1% of the revetment annually as follows:

Prevention of Direct Damages to Revetment at Long Beach

.01 x 10,000 tons revetment x $1.00 per ton = $1,000 per year

Reduction of wave attack will also result in a public benefit from prevention of direct damages to the Long Beach seawall and a private benefit from reduction of damages to the privately owned cottages, each estimated as $1,000 per year. The total evaluated annual benefits for the proposed Long Beach improvement are therefor $3,000.

23. Construction of the proposed mound at Pebbly Beach would reduce overtopping and washing of beach material onto the low bordering unpaved access road. This would result in a benefit by elimination of the temporary inconvenience to local residents and beach patrons until town forces clear the road and make it passable. The local nature and minor value of the benefits to be derived do not warrant consideration of Federal participation in a project for this purpose.

24. Interests. - There is no Federal interest in any of the projects considered since none of the shores are owned by the United States. All interests are non-Federal public or private. Non-Federal public interests, defined as the benefits accruing to a State or political subdivision thereof as a landowner, amount to $2,000 per year for the Long Beach project. Non-Federal private interests, defined as those accruing to property in other types of ownership, amount to $1,000 per year for the Long Beach project.

25. Justification. - The estimated annual benefits, annual costs and ratio of benefits to costs for the proposed Long Beach project are listed below:

Annual Benefits	$3,000
Annual Costs	$21,800
Ratio of Benefits to Costs	0.1

26. Apportionment of Costs. - The project for improvement and protection of Long Beach is not economically justified by evaluated benefits. Therefore, no portion of the cost is apportioned to the United States.

27. Coordination with Other Agencies. - Coordination has been maintained with the cooperating agency, the Division of Waterways of the Massachusetts Department of Public Works. The views of the cooperating agency were obtained during the progress of the study and they were considered in developing the proposed improvements. Officials of the town of Rockport were also consulted. The cooperating agency was invited to furnish comments on the findings of the study. The views of the Federal and State fish and wildlife agencies were requested concerning aspects of the study pertaining to their interests. The Massachusetts Water Resources Commission was also advised of the findings of the study.

28. Comments of Local Interests and Other Agencies. - The cooperating agency concurred in the findings of the study. It commented that since the study was requested protection of the principal problem area has been provided by seawall reconstruction and riprap revetment, that, in the future, sand may be placed periodically along the shore of Long Beach for nourishment and that the shingle mound at Pebbly Beach is sufficiently stable to protect the low value land in the rear. The Massachusetts Division of Fisheries and Game advised that the proposed work would not present any prospective detrimental effects to the fish and wildlife of the area, that further enhancement of the recreational aspects of the Long Beach project is possible if the tidal creek and approach channel

east of Long Beach is widened and deepened in obtaining fill for the beach, if a paved boat launching ramp is constructed bordering the tidal creek and if the training jetty is modified to permit angler access and facilitate public fishing. The United States Fish and Wildlife Service, in cooperation with the Massachusetts Division of Fisheries and Game, prepared a report on the effects of the proposed improvements on the fish and wildlife resources. It determined that the plan of protection and improvement for Long and Pebbly Beaches would have no detrimental effects. It reported that should borrow material be taken from the creek behind Long Beach and from the entrance channel parallel to the proposed jetty, some fishery benefits would be realized and that further benefits would be realized if the training jetty were capped to provide easy access for land-based fishermen wishing to fish the mouth of the deepened creek. The complete report of the U. S. Fish and Wildlife Service is included in Appendix F.

PART VI - CONCLUSIONS AND RECOMMENDATIONS

29. Conclusions. - Since 1851 erosion has resulted in loss and recession of beaches although some accretion has occurred since 1952.

30. Replacement of failed sections of the seawall and placement of riprap revetment along the toe of the new and existing wall during 1959 now provides adequate protection for the development at Long Beach from direct wave attack.

31. Continued loss of beach material from Long Beach, as has occurred at a slow rate over the period of record, could gradually expose the existing development to more severe wave attack and damages.

32. All beach areas are subject to minor damages from wave runup and landward movement of beach material.

33. The Division Engineer concludes that a practicable plan for improvement and protection of Long Beach, developed upon the request of the cooperating agency to increase the capacity of the bathing beach as needed and to insure that no damages occur to existing structures consists of widening 3,300 feet of beach by the direct placement of sand fill and construction of a 400-foot training jetty at the east end of the fill at the tidal creek at Cape Hedge, all as shown on Plate 7.

34. Improvement and protection of Long Beach is not justified by evaluated benefits. It is therefore not advisable for the United States to adopt a project authorizing Federal participation in the cost of construction.

35. Overtopping of the beach and transport of beach material onto the parking area at Cape Hedge Beach and onto the shore road at Pebbly Beach can be prevented or reduced by construction of barriers to landward movement. Construction of a barrier of the magnitude required at Cape Hedge Beach is not warranted by the limited use and lack of development of the area. A typical section of a stone mound which would be suitable for protection of the road at Pebbly Beach has been developed and it is shown on Plate 7.

36. Benefits could not be evaluated for the proposed mound for Pebbly Beach. Due to the local nature and minor value of the benefits to be derived, Federal participation in the cost of construction of a protective barrier is not advisable.

37. Additional information called for by Senate Resolution 148, 85th Congress, 1st Session adopted 28 January 1958 is contained in Appendix E of this report.

38. Recommendations. - It is recommended that no project be adopted for the protection or improvement of Long, Cape Hedge or Pebbly Beaches, Rockport, Massachusetts. It is further recommended that protective measures which may be undertaken by local interests based upon their determination of economic justification be accomplished in accordance with plans and methods considered in this report.

Incls
6 Appendices
7 Plates

SEYMOUR A. POTTER, JR.
Brigadier General, USA
Division Engineer

APPENDIX A

SAMPLES OF BEACH AND NEARSHORE MATERIAL

Samples of surface beach and nearshore materials were obtained along profiles 1, 3, 5, 8, and 11. Locations of the profiles are shown on Plate No. 1. Samples were obtained from the beaches at the seawall, berm, mean high water and/or mean sea water levels and from mean low water level, 6, 12, 18, 24 and 30 foot depths. A mechanical analysis was run of each sample and the results are included in Tables A-1, A-2 and A-3. Information in Table A-1 includes location of samples, grain size range, median diameters, character of material in percent, sorting and skewness coefficients. Tables A-2 and A-3 include cumulative weight percentages retained on various sieves for individual samples and for the average of all samples on each profile.

TABLE A-1
CHARACTERISTICS OF SAMPLES

PROFILE NO.	LOCATION ON PROFILE	GRAIN SIZE (m.m.) RANGE	GRAIN SIZE (m.m.) MEDIAN DIAMETER	CHARACTER OF MATERIALS (PERCENT) CLAY & SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	SORTING COEFFICIENT	SKEWNESS COEFFICIENT
1	Wall	0.070-0.42	0.29	0.1	99.9	-	-	-	1.23	1.02
	M.H.W.	0.060-0.42	0.29	1.2	98.8	-	-	-	1.23	1.02
	M.S.L.	0.033-0.42	0.29	1.6	98.4	-	-	-	1.22	1.03
	M.L.W.	0.060-0.42	0.25	1.0	99.0	-	-	-	1.27	1.14
	6'	0.074-19.10	0.26	-	82.7	11.5	1.7	4.1	1.29	1.19
	12'	0.074- 2.00	0.28	-	90.7	9.3	-	-	1.20	1.04
	18'	0.074- 2.00	0.22	-	94.8	5.2	-	-	1.20	1.06
	24'	0.070-2.38	0.16	2.2	93.5	5.3	-	-	1.29	0.94
	30'	0.070-2.00	0.14	5.3	91.1	3.6	-	-	1.34	0.92
Average	-	-	0.24	-	-	-				
3	Wall	0.14- 0.42	0.28	-	99.4	0.6	-	-	1.22	0.96
	M.H.W.	0.13- 0.42	0.29	-	99.7	0.3	-	-	1.22	1.00
	M.L.W.	0.070-0.84	0.29	1.1	94.1	4.8	-	-	1.20	0.96
	6'	0.074-2.00	0.28	-	85.4	14.6	-	-	1.23	1.03
	12'	0.074-2.00	0.28	-	86.5	13.5	-	-	1.24	0.94
	18'	0.070-2.00	0.25	0.5	91.2	8.3	-	-	1.23	0.96
	24'	0.070-2.00	0.20	1.3	93.7	5.0	-	-	1.40	1.08
	30'	0.061-2.00	0.14	6.9	88.9	4.2	-	-	1.42	1.06
Average			0.25							
5	Wall	0.065-0.46	0.26	0.4	95.2	4.4	-	-	1.34	0.96
	M.H.W.	0.050-0.42	0.29	1.3	97.2	1.5	-	-	1.20	1.07
	M.S.L.	0.030-0.44	0.30	1.1	95.9	3.0	-	-	1.22	1.10
	M.L.W.	0.060-0.85	0.30	1.0	90.6	8.4	-	-	1.26	1.08
	6'	0.074-2.00	0.30	-	87.7	12.3	-	-	1.20	1.00
	12'	0.074-2.00	0.26	-	83.1	16.9	-	-	1.22	0.96
	18'	0.065-2.00	0.23	0.7	92.7	6.6	-	-	1.19	1.07
	24'	0.067-2.38	0.22	0.9	93.5	5.6	-	-	1.23	1.00
	30'	0.064-2.00	0.17	4.2	89.7	6.1	-	-	1.38	1.08
Average			0.26							

TABLE A-1
CHARACTERISTICS OF SAMPLES

PROFILE NO.	LOCATION ON PROFILE	GRAIN SIZE (m.m.)		CHARACTER OF MATERIALS (PERCENT)					SORTING COEFFICIENT	SKEWNESS COEFFICIENT
		RANGE	MEDIAN DIAMETER	CLAY & SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL		
8	Berm	0.050-28.0	5.6	1.5	15.0	18.3	10.8	54.4	4.53	0.30
	M.H.W.	0.13-37.0	14.0	1.0	2.3	10.2	9.9	76.6	2.20	0.61
	M.S.L.	-			-	-	*5	*95	-	-
	M.L.W.	0.050-29.0	10.0	1.7	37.7	1.1	1.4	58.1	6.5	0.42
	6'	0.060-9.52	0.26	1.4	80.5	12.6	4.1	1.4	1.34	1.07
	12'	0.070-4.76	0.24	0.4	93.2	5.6	0.8	-	1.20	0.97
	18'	0.072-4.00	0.16	1.2	93.4	3.9	1.0	0.5	1.35	1.03
	30'		-		SEAWEED & 1½" GRAVEL				-	-
Average			3.0							
11	M.H.W.	4.76-25.4	-					*100	-	-
	M.S.L.	0.050-50.0	15.0	1.2	24.8	6.4	5.2	62.4	9.51	0.07
	M.L.W.	0.050-14.0	4.1	1.3	16.8	23.6	10.6	47.7	3.80	0.86
	6'	0.071-25.4	0.23	0.6	78.5	5.9	1.3	13.7	1.37	1.26
	12'	0.068-2.00	0.11	7.0	89.5	4.5	-	-	1.70	1.93
	18'		-		SEAWEED & 2" GRAVEL				-	-
	24'	-	-			Seaweed			-	-
	30'	-				Seaweed			-	-
Average			4.9							

*Visual Inspection

TABLE A-2

Sieve Analysis

U.S. Standard Sieve No.	3/4"	1/2"	3/8"	4	8	10	16	20	30	40	50	70	80	100	200	Pan
Diameter in mm	19.10	12.70	9.52	6.35	2.38	2.00	1.19	0.84	0.59	0.42	0.297	0.210	0.177	0.149	0.074	
Locations	Cumulative Weight Percentage Retained															
									Profile #1							
Wall								0.0	0.4*	0.6	44.0*	85.3	92.0*	96.8	99.9	100.0
M.H.W.								0.0	0.2*	0.4	32.0*	84.5	93.0*	98.0	98.8	100.0
M.S.L.								0.0	1.3*	1.9	48.0*	85.3	93.0*	96.8	98.4	100.0
M.L.W.								0.0	0.4*	0.7	44.0	63.9	91.0*	94.8	99.0	100.0
6'	0.0	2.9	3.6	4.1	5.1	5.8	7.7	9.1	11.5	17.3	31.3	67.4	80.4	88.4	100.0	100.0
12'							1.1	2.2	4.3	9.3	34.0	81.9	92.6	96.3	100.0	100.0
18'							0.8	1.6	2.7	5.2	18.6	63.4	80.3	89.1	100.0	100.0
24'					0.0	0.5	1.5	2.5	3.5	4.3	6.6	22.4	38.5	48.3	97.8	100.0
30'						0.0	0.8	1.4	2.5	3.6	5.3	15.6	28.5	38.0	94.7	100.0
Total	0.0	2.9	3.6	4.1	5.1	6.3	11.9	16.8	26.8	43.3	263.8	569.7	689.3	746.5	888.6	--
Average	0.0	0.32	0.40	0.46	0.57	0.70	1.3	1.87	3.0	4.8	29.3	63.3	76.6	82.9	98.7	100.0
									Profile #3							
Wall								0.0	0.3*	0.6	44.0*	86.2	92.0*	98.5	99.8	100.0
M.H.W.								0.0	0.2*	0.3	45.0*	86.2	91.0*	98.6	100.0	100.0
M.L.W.						0.0	0.2*	0.3	2.0*	4.8	50.0*	87.9	92.0*	97.3	98.9	100.0
6'						0.0	1.0	2.3	5.1	14.6	35.0	80.0	90.3	94.6	100.0	100.0
12'							1.6	2.7	4.8	13.5	35.5	78.9	90.0	95.0	100.0	100.0
18'						0.0	1.9	2.6	4.0	8.3	23.7	69.1	82.6	89.6	99.5	100.0
24'						0.0	1.8	2.6	3.7	5.0	9.1	36.0	54.1	62.9	98.7	100.0
30'						0.0	1.5	2.4	3.3	4.2	6.0	18.1	29.8	38.9	93.1	100.0
Total						0.0	7.8	12.9	23.1	51.3	248.3	542.4	621.8	675.4	790.0	--
Average						0.0	0.98	1.6	2.9	6.4	31.0	67.8	77.7	84.4	98.8	100.0

Note: *Estimated

TABLE A-3
SIEVE ANALYSIS

U.S. Standard Sieve No. in M.M.	2" 50.8	1½" 38.1	1" 25.4	3/4" 19.10	½" 12.70	3/8" 9.52	¼" 6.35	4 4.76	8 2.38	10 2.00	16 1.19	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
Locations	CUMULATIVE WEIGHT PERCENT RETAINED																			
									Profile #5											
Wall												0.0	*2.0	4.4	*40.0	71.2	*83.0	93.0	99.6	100.
M.H.W.												0.0	*3.0	1.5	*50.0	89.1	*92.0	97.4	98.7	100.
M.S.L.												0.0	*1.0	3.0	*50.0	88.5	*93.0	98.5	98.9	100.
M.L.W.										0.0		0.3	*4.0	8.4	*50.0	86.9	*93.0	97.3	99.0	100.
6'										0.0	1.4	2.3	4.6	12.3	31.5	68.6	82.5	90.7	100.0	100.
12'										0.0	1.8	3.2	6.6	16.9	42.9	81.4	90.4	94.0	100.0	100.
18'										0.0	1.9	2.7	3.5	6.6	18.9	60.8	77.4	84.6	99.3	100.
24'									0.0	0.4	1.7	2.3	3.2	5.6	13.9	49.4	67.1	76.1	99.1	100.
30'										0.0	1.0	1.7	3.2	6.1	11.7	29.8	42.9	51.2	95.8	100.
Total									0.0	0.4	7.8	12.5	31.1	64.8	308.9	625.7	721.3	782.8	890.4	-
Average									0.0	0.4	0.9	1.4	3.5	7.2	34.3	69.5	80.1	87.0	98.9	100.
									Profile #8											
Berm		0.0	5.4	15.7	23.4	34.2	*47.0	54.4	*63.0	65.2	*68.0	72.1	*78.0	83.5	*91.0	97.5	*98.0	98.3	98.5	100.
M.H.W.		0.0	24.4	34.6	51.8	60.3	*73.0	76.6	*83.0	86.5	*91.0	93.6	*96.0	96.7	*98.0	98.8	*98.8	98.9	99.0	100.
M.L.W.		0.0	11.3	35.0	43.8	50.7	*56.0	58.1	*59.0	59.5	*59.6	59.8	*60.2	60.6	*75.0	85.9	*91.0	97.2	98.3	100.
6'							0.0	1.4	4.6	5.5	8.5	10.3	12.6	18.1	33.3	70.3	81.4	86.9	98.6	100.
12'								0.0	0.4	0.8	1.9	2.6	3.7	6.4	16.6	54.7	70.4	77.7	99.6	100.
18'						0.0	*0.3	0.5	1.0	1.5	2.5	3.2	4.2	5.4	8.8	25.6	42.9	52.0	98.8	100.
30'	0.0	**100.0																		
Total	0.0	0.0	41.1	85.3	119.0	145.2	176.3	191.0	211.0	219.0	231.5	241.6	254.7	270.4	322.7	432.8	482.5	511.0	592.8	-
Average	0.0	0.0	6.9	14.2	19.8	24.2	29.4	31.8	35.2	36.5	38.6	40.3	42.5	45.1	53.8	72.1	80.4	85.2	98.8	100.
									Profile #11											
M.S.L.	0.0	26.6	42.4	44.9	52.0	54.1	*60.5	62.4	*66.5	67.6	*68.0	68.6	*72.0	74.0	*91.0	95.1	*97.5	98.2	99.4	100.
M.L.W.				0.0	7.0	21.7	*38.0	47.7	*57.0	58.3	*66.0	70.0	*76.0	81.9	*92.0	96.3	*97.5	98.3	98.7	100.
6'			0.0	9.1	*11.0	11.6	*13.0	13.7	14.3	*15.3	15.6	16.9	18.4	20.4	28.1	58.5	72.2	79.4	99.4	100.
12'										0.0	0.8	1.6	2.4	3.5	5.3	10.6	16.9	22.7	93.0	100.
18'	***S.W.																			
24'	***S.W.																			
30'	***S.W.																			
Total	0.0	26.6	42.4	54.0	70.0	87.4	111.5	123.8	137.8	141.2	150.4	157.1	168.8	179.8	216.4	260.5	284.1	298.6	390.4	-
Average	0.0	6.7	10.6	13.5	17.5	21.9	27.9	31.0	34.5	35.3	37.6	39.3	42.2	45.0	54.1	65.1	71.0	74.7	97.6	100.

* Estimated
** Not included in averages
*** Seaweed

APPENDIX B

PREVAILING WINDS AND STORMS

1. Prevailing Winds. - United States Weather Bureau wind records for Boston, Massachusetts, the nearest weather station, located approximately 30 miles southeast of the study area shown that prevailing winds approach the study area from westerly directions. A wind diagram based on hourly observations of wind speeds and directions for the ten year period from October 1949 through September 1959, inclusive, is shown on Plate No. 1. It indicates a high preponderance of westerly winds with the greatest duration from the southwest direction and little difference in duration between the northeast and southeast quadrants. The study area faces open water from the east through the southeast. Of these directions winds of the greatest duration are from the southeast. Winds from the southeast quadrant, although relatively infrequent, approach over an unlimited fetch of open sea and they can therefore generate large waves which directly approach the shoreline of the study area.

2. Storm Winds. - A summary of the number of storms compiled from records of the United States Weather Bureau at Boston, Massachusetts covering the 75-year period 1870-1945, inclusive, is given in the following table:

Storms (1870-1945, inclusive)

Direction	N	NE	E	SE	S	SW	W	NW	Total
No. of storms	3	80	9	14	12	15	13	14	160
Percent of total	2	50	6	9	7	9	8	9	100

The above storms represent major distrubances accompanied by high wind speeds of long duration. Classification of direction of each storm was made in accordance with the predominant direction of wind. Variations in direction during storms are not accounted for.

3. A tabulation showing the duration of winds, their direction and speeds compiled from United States Weather Bureau records at Boston for the period October 1949 to September 1959 is included in Table B-1.

TABLE B-1

WIND SPEEDS AND DIRECTIONS (OCTOBER 1949 - SEPTEMBER 1959 INCLUSIVE)

BOSTON, MASSACHUSETTS

NUMBER OF HOURS

Wind Speed (M.P.H.) / Direction	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & Over	Total	% Total Duration	Average Speed M.P.H.	Wind Movement Miles	% Total Movement	% Duration per Degree
N	124	703	1,681	1,344	380	125	15	3	-	4,375	5.0	12.2	53,481	4.6	0.22
NNE	92	438	985	832	382	166	31	5	1	2,932	3.3	13.4	39,356	3.4	0.15
NE	117	553	1,068	1,056	533	235	87	32	11	3,692	4.2	14.4	53,268	4.6	0.19
ENE	120	512	908	1,027	459	219	55	16	4	3,320	3,8	14.1	46,825	4.0	0.17
E	137	537	1,376	1,321	383	140	50	22	2	3,968	4.5	13.0	51,756	4.5	0.20
ESE	136	631	1,616	1,396	268	68	14	-	4	4,133	4,7	11.6	48,134	4.2	0.21
SE	124	636	1,370	974	135	26	-	-	1	3,266	3.7	11.0	35,797	3.1	0.16
SSE	98	618	1,150	508	93	27	3	2	1	2,500	2.9	10.3	25,646	2.2	0.13
S	128	912	1,591	958	251	62	13	3	-	3,918	4.5	11.0	42,967	3.7	0.20
SSW	122	905	2,081	1,911	691	217	48	16	3	5,994	6.8	13.1	78,554	6.8	0.30
SW	118	1,061	4,098	4,357	1,188	278	35	4	-	11,139	12.7	13.2	147,485	12.8	0.56
WSW	96	686	2,259	2,329	557	103	17	1	-	6,048	6.9	12.7	76,984	6.7	0.31
W	89	695	2,162	2,361	891	274	69	6	-	6,547	7.5	14.0	91,469	7.9	0.33
WNW	93	929	3,017	3,406	1,491	564	71	11	-	9,582	10.9	14.5	138,485	12.0	0.48
NW	102	845	2,587	3,479	1,558	635	109	7	4	9,326	10.7	15.0	140,066	12.1	0.48
NNW	94	633	2,011	2,418	902	203	23	4	-	6,286	7.2	13.7	86,274	7.4	0.32
Calms										606	0.7				
Totals	1,790	11,294	29,960	29,677	10;162	3,342	640	132	31	87,632	100.0	13.0	1,156,547	100.0	

APPENDIX C

TIDES

1. General. - Tides in the study area are semi-diurnal. Mean ranges at Rockport Harbor and Ten Pound Island, Gloucester Harbor are 8.6 and 8.7 feet respectively and corresponding spring ranges are 10.0 and 10.1 feet.

2. Tidal Observations. - Tidal observations by the United States Coast and Geodetic Survey were analyzed for a 30-1/3 year period at Boston Harbor from August 1921 to March 1952 and at Gloucester Harbor for the period July 20 to October 26, 1928.

3. High Tides. - A comparison was made between the 188 high tides at Gloucester Harbor and the corresponding high tides at Boston Harbor to determine whether variations from the mean range were comparable. There was no difference between the variations for 93 high tides, a difference of 0.1 of a foot for 75 tides, 0.2 for 15 tides, 0.3 for 3 tides, 0.4 for 1 tide and 0.8 for 1 tide. The close agreement between the variations in tidal heights from the planes of mean high water at each location indicates that variations from the mean in the study area are similar to those which occur in Boston Harbor. The total and average annual number of occurrences of high tides which exceeded the mean height by 2.0 feet or more at Boston Harbor based on the 30-1/3 year record are given in Table C-1 in increments of one-tenth foot.

TABLE C-1

TIDES EXCEEDING MEAN HEIGHT AT BOSTON HARBOR, MASS.

Feet Above MHW	Number of Occurrences*	Average Number of Occurrences Per Year*
4.3	1	0.03
4.2	2	0.06
4.1	2	0.06
4.0	2	0.06
3.9	2	0.06
3.8	2	0.06
3.7	3	0.1
3.6	4	0.1
3.5	5	0.2
3.4	7	0.2
3.3	14	0.5
3.2	21	0.7
3.1	32	1.1
3.0	44	1.5
2.9	67	2.2
2.8	83	2.7
2.7	110	3.6
2.6	144	4.8
2.5	205	6.8
2.4	277	9.1
2.3	358	11.8
2.2	463	15.3
2.1	560	18.5
2.0	741	24.5

*Equaling for exceeding the stated elevation.

APPENDIX D

DESIGN ANALYSIS

1. General. - A stone training jetty was designed for the tidal creek at the east end of Long Beach based on the maximum wave height expected to occur at the site using a tide elevation which occurs on an average once a year. The design wave height was computed using the solitary wave formula $d/H = 1.28$ where d is the depth of water at breaking and H is the wave height. Sizes and slopes of armor stone were computed using the United States Army Waterways Experiment Station formula.

$$Wr = \frac{\gamma r\ H^3}{K_\Delta\ (Sr-1)^3 \cot \alpha}$$

where
- Wr is the weight of armor stone
- γr is the specific weight of armor stone in pounds per cubic foot
- K_Δ is a dimensionless experimental coefficient
- H is the design wave height
- Sr is the specific gravity of the armor unit relative to the water in which the structure is located equal to $\gamma r / \gamma w$ where γw is the specific weight of the water in pounds per cubic foot
- α is the angle of the breakwater slope

2. Design Wave. - The design tide is 11.8 feet. The ground or bottom elevation at the outer end of the jetty is 3.0 feet above mean low water. Assuming that waves break at the end of the structure, the design depth of breaking d is 11.8 - 3.0 or 8.8 feet and from $d/H = 1.28$, $H = \frac{8.8}{1.28} = 6.9$ feet. From the Waterways Experiment Station and solitary wave formulas, assuming a stone size of one (1) ton, the wave height H was computed as 5.6 feet, the depth at breaking as 7.2 feet and the height of the bottom as 4.6 feet above mean low water. This height exists 70 feet shoreward of the outer end of the jetty. For design purposes a wave height of 6.9 feet was used for determining armor stone sizes and slopes for the outer 100 feet of the jetty and a minimum size armor stone of one ton with side slopes of 1 on 1.5 was used for the rest of the structure.

3. Stone Sizes. - The size of armor stones from the WES formula was computed using:

$\gamma r = 165$
$\gamma w = 64.0$
$H = 6.9$ feet for the outer 100 feet of jetty
$K_{\Delta} = 2.5$
$Sr = \frac{165}{64} = 2.58$
$\cot\alpha = 1.5$

from which Wr = 3830 lbs. or 1.92 tons. Based on an assumption that stones are cubical in shape, the stones would measure 2.83 feet on a side. Use of a top width of two armor stone diameters therefore requires a minimum top width of jetty of 5.66 feet. Use of a 6-foot top width along the outer 100 feet of jetty would therefore be satisfactory. Along the remainder of the jetty where a minimum size armor stone of one ton is specified, a top width of 5 feet would be satisfactory. Size of core stone to make a sand-tight structure was based on use of stone 1/10th of the weight of the armor stone. Use of successive reductions of stone sizes in layers is impractical without increasing the size of the jetty. A core for the outer 100 feet consisting of quarry run stone of assorted sizes up to 400 pounds with not less than 50 percent between 350 and 400 pounds is considered to be a satisfactory compromise. Similarly a core for the rest of the jetty of quarry run stone of assorted sizes up to 200 pounds with not less than 50 percent between 150 and 200 pounds is considered satisfactory.

APPENDIX E

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF ROCKPORT, MASSACHUSETTS

INFORMATION CALLED FOR BY SENATE RESOLUTION 148, 85TH CONGRESS, ADOPTED 28 JANUARY 1958

1. Beach Erosion Problems. - The study covers the shore of Rockport, Massachusetts, including Long, Cape Hedge and Pebbly Beaches, on the south side of Cape Ann between Brier Neck and Lands End. The problem consists of erosion of the beaches, particularly during storms, damages to the existing protective structures and development, overtopping of beaches by wave runup with consequent deposition of beach material and debris on backshore areas and the meandering of a tidal creek across Long Beach. The shore is directly exposed to wave action from the southeast quadrant across the Atlantic Ocean. The mean range of tide is 8.6 feet and the spring range is 10.0 feet. The highest tide experienced at Gloucester Harbor is 4.3 feet above mean high water.

2. Improvements Considered. - Plans of protection and improvement were developed as follows:

a. Long Beach. - Widening 3,300 feet of beach by the direct placement of sand fill and construction of a 400-foot training jetty at the east end of the fill at the tidal creek at Cape Hedge.

b. Pebbly Beach. - Construction of a barrier to reduce overtopping and landward movement of beach material.

3. Conclusions and Recommendations. - The existing seawall and revetment at Long Beach are adequate for protection of the development. Construction of a barrier to prevent or reduce landward movement of beach material at Cape Hedge Beach is not warranted due to the magnitude of the structure needed and the limited use and lack of development in the area. Improvement and protection of Long Beach is not justified by evaluated benefits. Benefits from the proposed mound, which could not be evaluated, would be of a local nature and minor value. It was therefore recommended that no project be adopted by the United States for any of the beaches studied. It was further recommended that protective measures which may be undertaken by local interests based upon their determination of economic justification be accomplished in accordance with plans and methods considered in this report. The estimated costs and benefits, based on August 1961 price levels, a 50-year economic life and a 3.5 percent interest rate for investments which are all non-Federal are listed below:

Long Beach (Sand Fill and Jetty)

Estimated First Cost	$184,000
Estimated Annual Charges	21,800
Estimated Annual Benefits	3,000
Benefit-Cost Ratio	0.14

Pebbly Beach (Stone Mound)

Estimated First Cost Per Linear Foot	$ 21.00

4. Discussion. - Analysis on the basis of an economic life of 100 years would not result in modification of the findings in the report. The benefit-cost ratio for the Long Beach project would increase from 0.14 to 0.15. The benefits from the Pebbly Beach project would still be comparatively minor.

COMMENTS OF THE U. S. FISH AND WILDLIFE SERVICE

ADDRESS ONLY THE
REGIONAL DIRECTOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
59 TEMPLE PLACE
BOSTON, MASSACHUSETTS

NORTHEAST REGION
(REGION 5)
MAINE
NEW HAMPSHIRE
NEW YORK
VERMONT
PENNSYLVANIA
MASSACHUSETTS
NEW JERSEY
RHODE ISLAND
DELAWARE
CONNECTICUT
WEST VIRGINIA

September 27, 1961

Division Engineer
New England Division
U. S. Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Dear Sir:

Reference is made to your letter of August 8, 1961 transmitting to this office plans presently being considered by your office for the protection and improvement of Long Beach and Pebbly Beach, Rockport, Cape Ann, Massachusetts, and in which you request comments from this office on the effects of the proposed improvements on the fish and wildlife resources. This letter constitutes our conservation and development report. It was prepared in cooperation with the Massachusetts Division of Fisheries and Game and has the concurrence of that agency.

It is understood that as a result of a beach erosion control study being made of the south shore of Cape Ann, Massachusetts, plans for the protection and improvement are being considered for 2 beaches as follows:

1. Long Beach, Rockport: Widening 3,300 feet of beach by the direct placement of sand fill and construction of a 400-foot training jetty at the east end of the fill at the tidal creek at Cape Hedge.

2. Pebbly Beach, Rockport: Construction along the seaward edge of the shore road of a stone mound or other barrier to landward movement of beach material.

It is further understood that sand fill for the beach widening may be obtained from inland borrow pits. There is a possibility that fill could be obtained from the marsh area bordering the tidal creek behind Long Beach. During further contact with your office by phone regarding the borrow areas it was learned that probings in the marsh to date had not given sufficient information on the suitability of the subsurface material for beach-fill use and, also, that if fill were obtained from behind the beach, the borrowing would likely be close to and in the existing creek bed. This would result in widening and deepening the existing creek bed.

It has been determined that the plan of protection and improvement as presently envisioned for Long and Pebbly Beaches would have no detrimental effects on the fish and wildlife resources. No commercial fishery aspects are involved.

Should borrow material be taken from the creek behind Long Beach and the operation be extended seaward parallel to the planned training jetty, some fishery benefits would be realized. Further benefits would be realized if the training jetty were capped to provide easy access for land-based fishermen wishing to fish the mouth of the deepened creek. It should be noted that a town parking area exists at the end of Seaview Street behind Cape Hedge Beach. This might provide an opportunity to utilize profitably unsuitable borrow material for extending the town parking area. This feature would require further negotiations with local interests and would be accomplished by representatives of the Massachusetts Division of Fisheries and Game.

No further report by this agency is considered necessary.

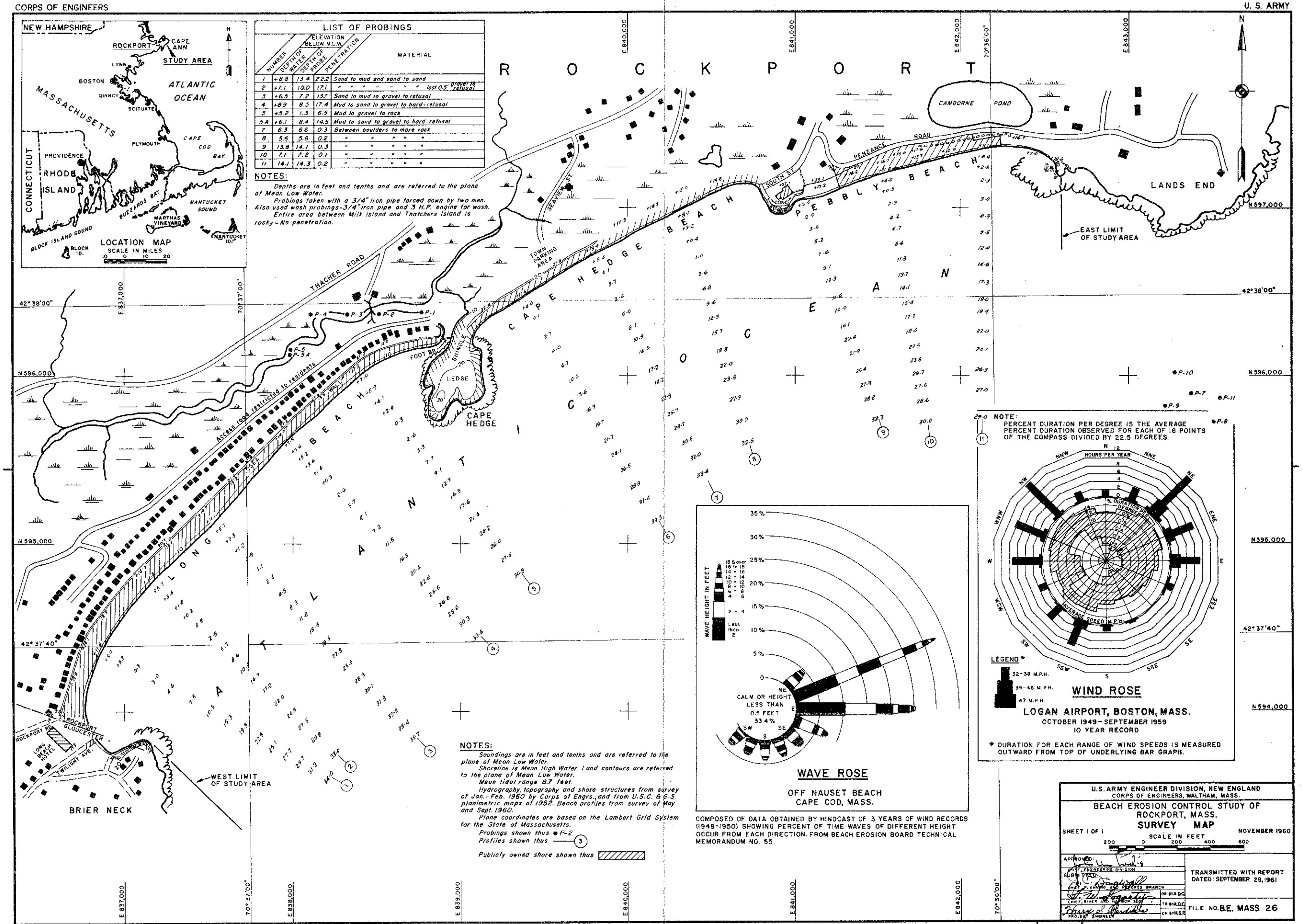
Thank you for giving us the opportunity to report on this project.

Sincerely yours,

John S. Gottschalk
Regional Director

CORPS OF ENGINEERS

U. S. ARMY



LIST OF PROBINGS				
NUMBER	ELEVATION BELOW M.L.W. DEPTH OF WATER	DEPTH OF PROBE	PENETRATION	MATERIAL
1	+8.8	13.4	22.2	Sand to mud and sand to sand
2	+7.1	10.0	17.1	" " " " " " " lost 0.5' gravel to refusal
3	+6.5	7.2	13.7	Sand to mud to gravel to refusal
4	+8.9	8.5	17.4	Mud to sand to gravel to hard-refusal
5	+5.2	1.3	6.5	Mud to gravel to rock
5A	+6.1	8.4	14.5	Mud to sand to gravel to hard-refusal
7	6.3	6.6	0.3	Between boulders to more rock
8	5.6	5.8	0.2	" " " " "
9	13.8	14.1	0.3	" " " " "
10	7.1	7.2	0.1	" " " " "
11	14.1	14.3	0.2	" " " " "

NOTES:

Depths are in feet and tenths and are referred to the plane of Mean Low Water.

Probings taken with a 3/4" iron pipe forced down by two men. Also used wash probings-3/4" iron pipe and 3 H.P. engine for wash.

Entire area between Milk Island and Thatchers Island is rocky—No penetration.

NOTES:

Soundings are in feet and tenths and are referred to the plane of Mean Low Water.

Shoreline is Mean High Water. Land contours are referred to the plane of Mean Low Water.

Mean tidal range 8.7 feet.

Hydrography, topography and shore structures from survey of Jan.-Feb. 1960 by Corps of Engrs., and from U.S.C. & G.S. planimetric maps of 1952. Beach profiles from survey of May and Sept. 1960.

Plane coordinates are based on the Lambert Grid System for the State of Massachusetts.

Probings shown thus ● P-2

Profiles shown thus —(3)

Publicly owned shore shown thus

COMPOSED OF DATA OBTAINED BY HINDCAST OF 3 YEARS OF WIND RECORDS (1948-1950) SHOWING PERCENT OF TIME WAVES OF DIFFERENT HEIGHT OCCUR FROM EACH DIRECTION. FROM BEACH EROSION BOARD TECHNICAL MEMORANDUM NO. 55.

NOTE:
PERCENT DURATION PER DEGREE IS THE AVERAGE PERCENT DURATION OBSERVED FOR EACH OF 16 POINTS OF THE COMPASS DIVIDED BY 22.5 DEGREES.

* DURATION FOR EACH RANGE OF WIND SPEEDS IS MEASURED OUTWARD FROM TOP OF UNDERLYING BAR GRAPH.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF ROCKPORT, MASS.

SURVEY MAP

SHEET 1 OF 1 — NOVEMBER 1960

SCALE IN FEET

APPROVED: CHIEF, ENGINEERING DIVISION

SUBMITTED: CHIEF, PLANNING AND REPORTS BRANCH

CHIEF, RIVER AND HARBOR SECT.

PROJECT ENGINEER

DR. BY A.D.C. TR BY A.D.C. CH BY H.S.P.

TRANSMITTED WITH REPORT DATED: SEPTEMBER 29, 1961

FILE NO. B.E. MASS. 26

PLATE NO. 1

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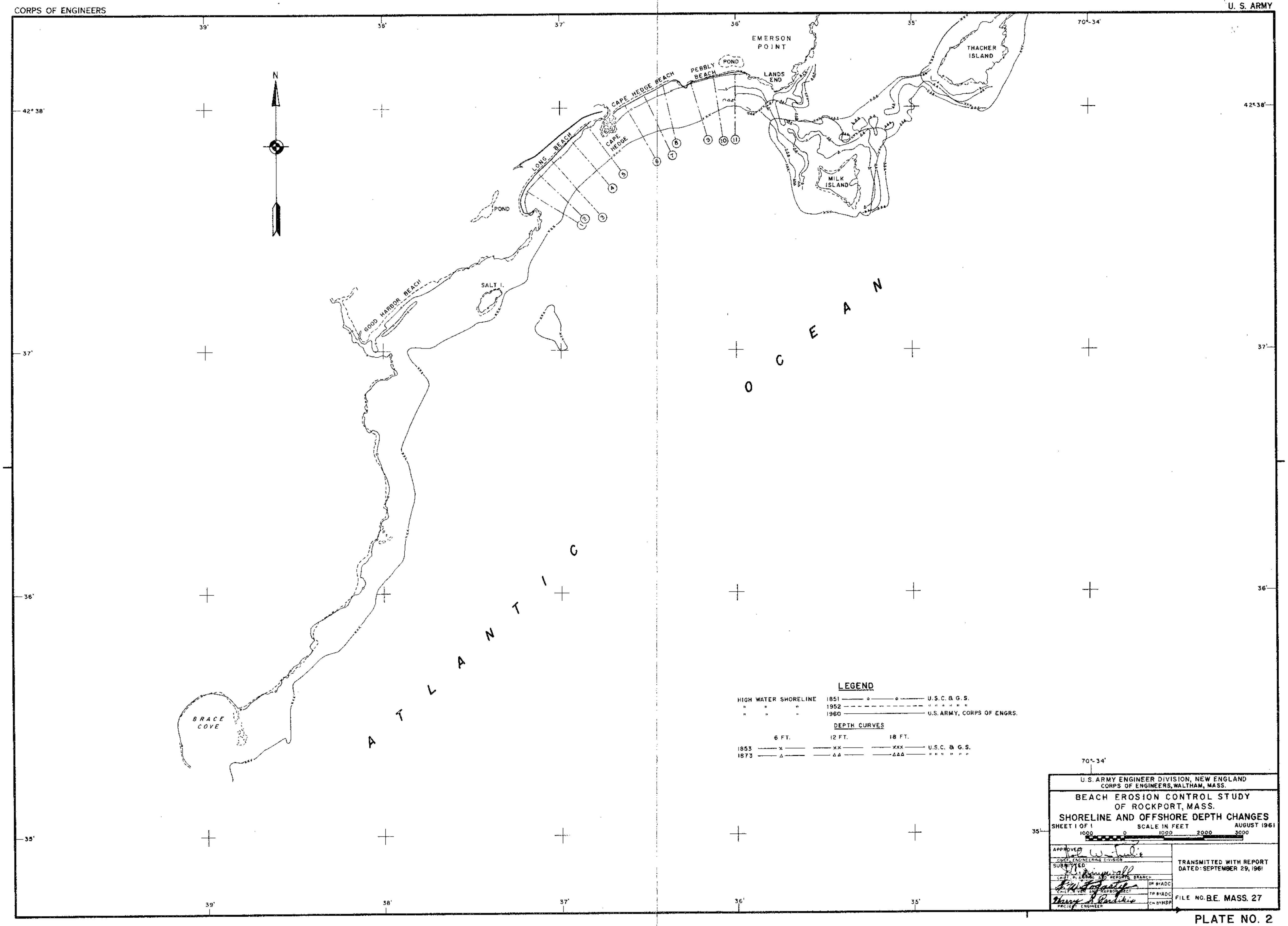
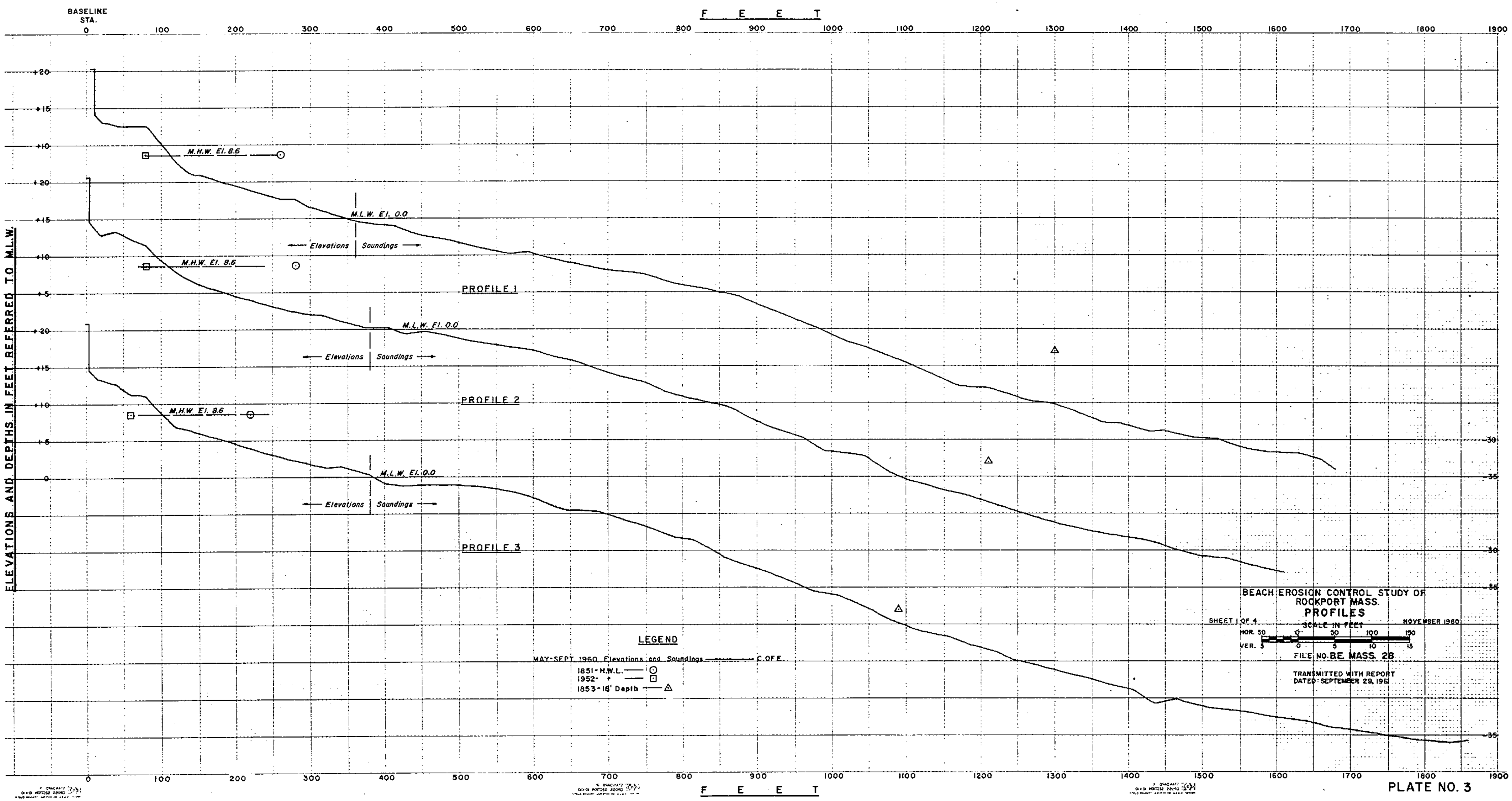


PLATE NO. 2


BASELINE STA.
F E E T
ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.
M.H.W. El. 8.6
M.L.W. El. 0.0
Elevations
Soundings
PROFILE 1
PROFILE 2
PROFILE 3
LEGEND
MAY-SEPT. 1960 Elevations and Soundings C.OF E.
1851-H.W.L.
1952- "
1853-18' Depth
BEACH EROSION CONTROL STUDY OF
ROCKPORT MASS.
PROFILES
SHEET 1 OF 4
NOVEMBER 1960
SCALE IN FEET
HOR. 50 0 50 100 150
VER. 5 0 5 10 15
FILE NO. B.E. MASS. 28
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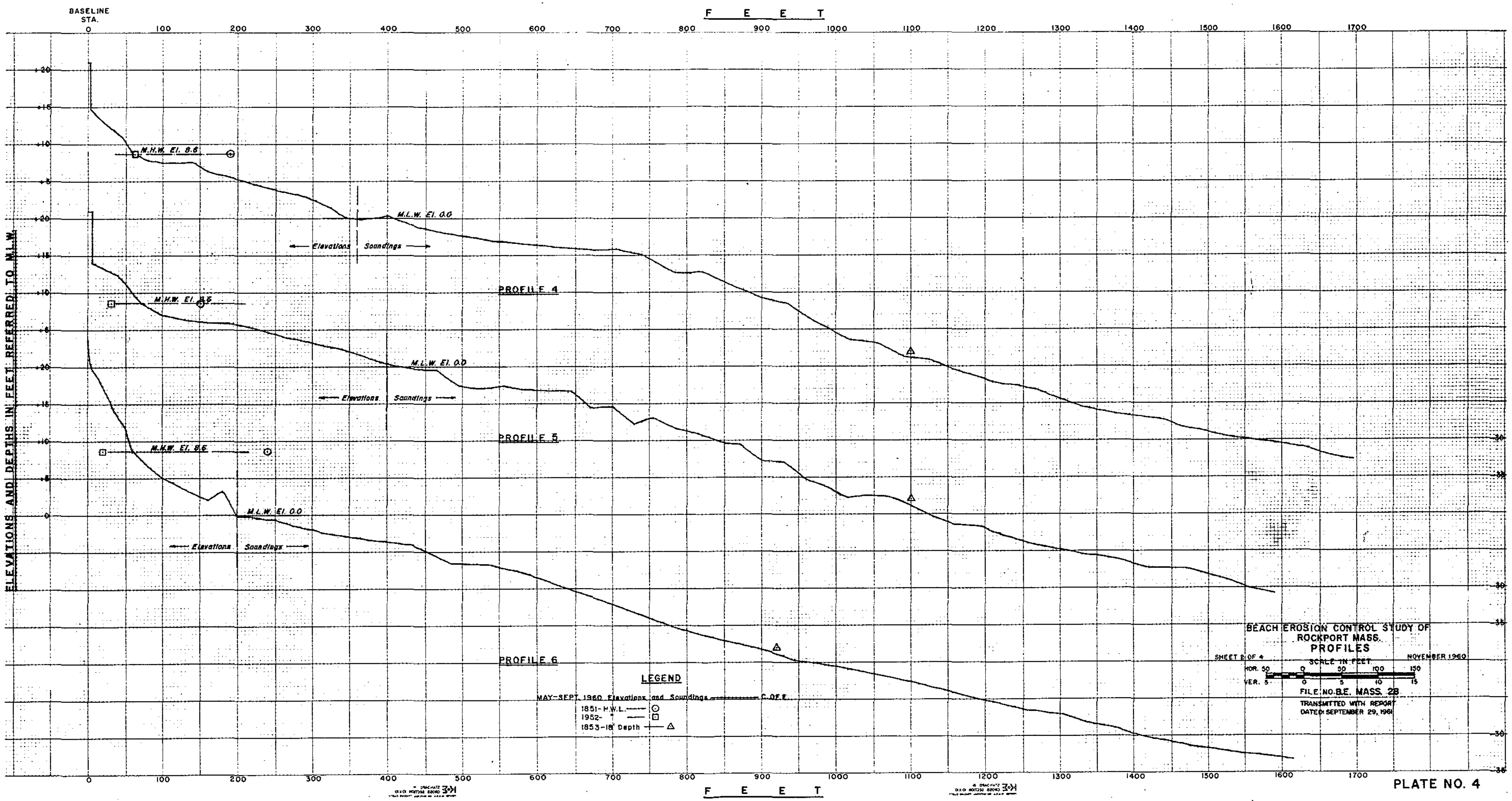
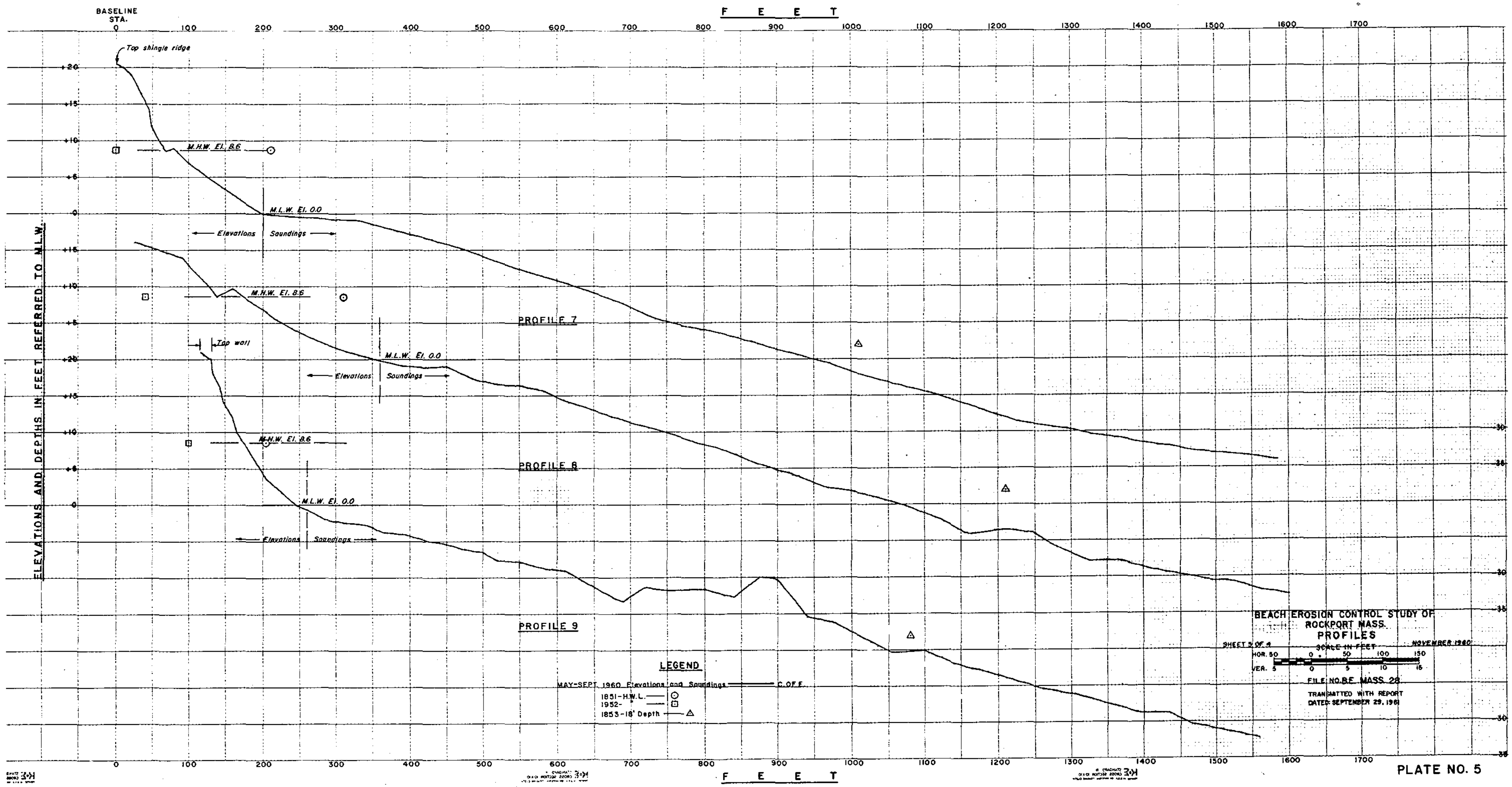
DATED: SEPTEMBER 29, 1961

PLATE NO. 3



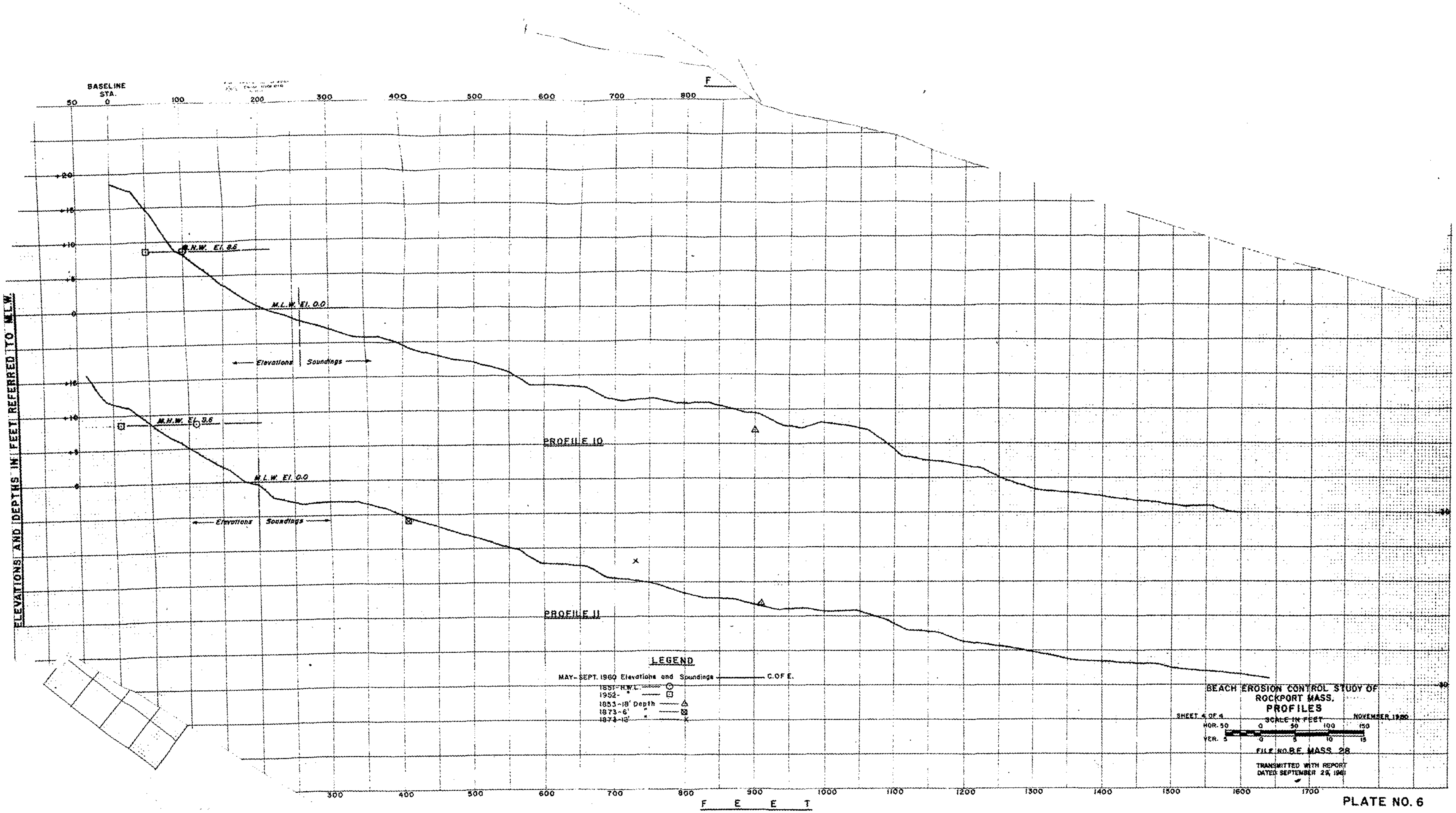
BASELINE STA.
F E E T
ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.
M.H.W. El. 8.6
M.L.W. El. 0.0
← Elevations Soundings →
PROFILE 4
PROFILE 5
PROFILE 6
LEGEND
MAY-SEPT. 1960 Elevations and Soundings C. OF E.
1851- H.W.L.
1952- "
1853-18' Depth
BEACH EROSION CONTROL STUDY OF
ROCKPORT MASS.
PROFILES
SHEET 2 OF 4
NOVEMBER 1960
SCALE IN FEET
HOR. 50 0 50 100 150
VER. 5 0 5 10 15
FILE NO. B.E. MASS. 28
TRANSMITTED WITH REPORT
DATED: SEPTEMBER 29, 1961

PLATE NO. 4



BEACH EROSION CONTROL STUDY OF ROCKPORT MASS.
PROFILES
SHEET 5 OF 4 SCALE IN FEET NOVEMBER 1960
HOR. 50 0 50 100 150
VER. 5 0 5 10 15
FILE NO. B.E. MASS. 28
TRANSMITTED WITH REPORT DATED SEPTEMBER 29, 1961

PLATE NO. 5



BASELINE STA.
50
0
100
200
300
400
500
600
700
800
F
+20
+15
+10
+5
0
M.H.W. El. 8.6
M.L.W. El. 0.0
Elevations
Soundings
PROFILE 10
+15
+10
+5
0
M.H.W. El. 8.6
M.L.W. El. 0.0
Elevations
Soundings
PROFILE 11
ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.
LEGEND
MAY-SEPT. 1960 Elevations and Soundings C.OF E.
1851-H.W.L.
1952- "
1853-18' Depth
1873-6' "
1873-12' "
BEACH EROSION CONTROL STUDY OF
ROCKPORT MASS.
PROFILES
SHEET 4 OF 4
NOVEMBER 1960
SCALE IN FEET
HOR. 50 0 50 100 150
VER. 5 0 5 10 15
FILE NO. B.E. MASS. 28
TRANSMITTED WITH REPORT
DATED SEPTEMBER 29, 1961
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
F E E T

PLATE NO. 6

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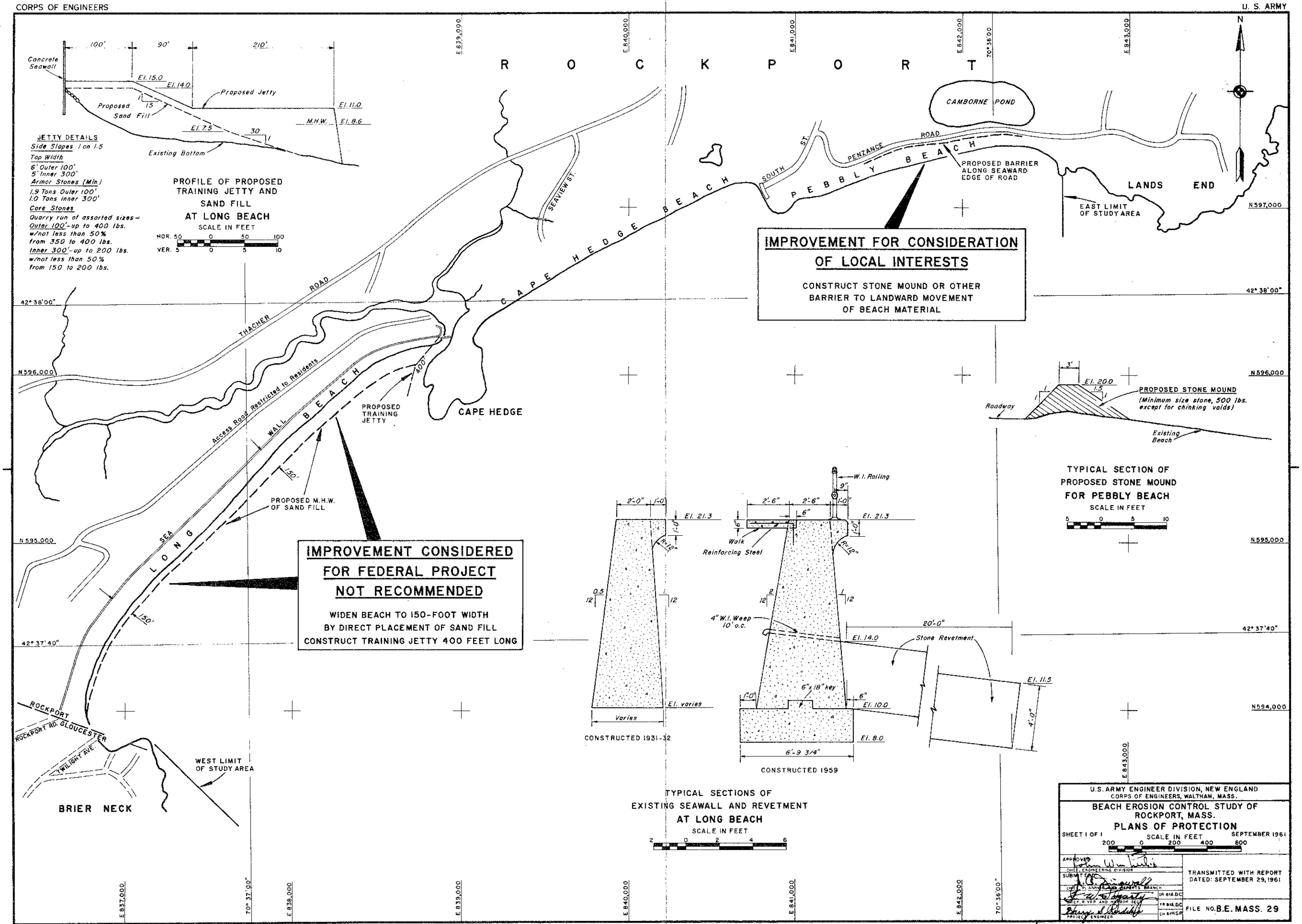

PLATE NO. 7